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Review of Recent Icing Accidents, Incidents, and NTSB Recommendations Regarding In-flight Icing

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Major Accidents: In-flight Icing

- 1994 Roselawn, IN, ATR-72 Turboprop, 68 fatal
 - Holding in Severe Icing
 - 4 ATR icing incidents prior to accident
 - Generated several recommendations to FAA regarding icing certification
- 1997 Monroe, MI, Comair 3272, EMB-120 Turboprop, 39 fatal
 - Encountered icing conditions while on approach
 - Deice boots not activated
 - 6 EMB-120 icing incidents prior to accident
 - Generated additional icing certification recommendations to FAA

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Icing Accidents and Incidents Since Comair 3272

Includes severe icing, ground icing, intercycle icing,
undetected icing

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Recent In-flight Icing Accidents/Incidents

(not a complete list)

1998 Sacramento, CA, Westair 7233 EMB-120 Turboprop

- Non fatal, during Comair 3272 investigation
- Several roll excursions after autopilot disconnect during turn
- Boots on (heavy mode); Pilots did not observe any intercycle accretions or ice aft of boot

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Recent In-flight Icing Accidents/Incidents

(not a complete list)

- 1997 Fredericton, Canada, Canadair Regional Jet (CRJ)
 - Non-fatal Accident
 - Airplane crashed during attempted go-around
 - Icing was a factor
 - Investigated by TSB Canada

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Recent In-flight Icing Accidents/Incidents

(not a complete list)

- Nov. 1998 Melbourne, Australia, Saab 340 Turboprop.
 - Non-fatal incident investigated by BASI
 - Autopilot disconnect and loss of roll control
 - 4 Saab 340 icing incidents prior to incident
 - BASI reiterated several COM3272 recommendations

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Recent In-flight Icing Accidents/Incidents

- Dec. 1998, Cottbus, Germany, ATR-42 Turboprop
 - Non-fatal incident investigated by BFU
 - At autopilot disconnect, several large roll excursions and 3,700 foot loss of altitude
 - German BFU determined aircraft entered and continued operation in severe icing conditions

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Recent In-flight Icing Accidents/Incidents

May 2001, Malatya, Turkey, CASA CN-235 Turboprop, Military Aircraft



- 34 fatalities
- Safety Board assisted Turkish Military with FDR/CVR
- FDR data was consistent with an icing encounter

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Airframe Structural Icing

Cessna 208B Caravan:



- Single-engine turboprop airplane
- Seat 10 pax, or haul freight
- 6 icing-related accidents (5 fatal) in last 2 years

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Cessna 208B Suspected Icing

Accidents: 2001-2003

- April 28, 2001 – Argentina (*10 fatal*)
- May 5, 2001 – Steamboat Springs, CO (*1 fatal*)
- Oct.10, 2001 – Dillingham, AK (*10 fatal*)
- March 6, 2002 – Barrow, AK (*5 seriously injured*)
- March 15, 2002 – Alma, WS (*1 fatal*)
- Nov. 8, 2002 – Parks, AZ (*4 fatal*)

26 Total Fatalities and 5
Seriously Injured

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Suspected Airframe Icing: Bombardier Challenger CL-600 Birmingham, England – Jan. 4, 2002



- 5 fatalities
- Crashed During Takeoff
- Was not de-iced prior to takeoff
- UK AAIB investigating with NTSB participation

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Suspected Airframe Icing: ATR 72-200 Freighter Penghu Channel, Taiwan – Dec. 21, 2002

- 2 fatalities
- Initial upset during cruise at 17,900 feet; 90 degree left roll
- Crew recognized severe icing conditions
- Taiwan ASC investigating

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Detailed Analysis of One Accident

Intercycle Icing Case

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March 19 2001

Comair Flight 5054 EMB-120 Incident

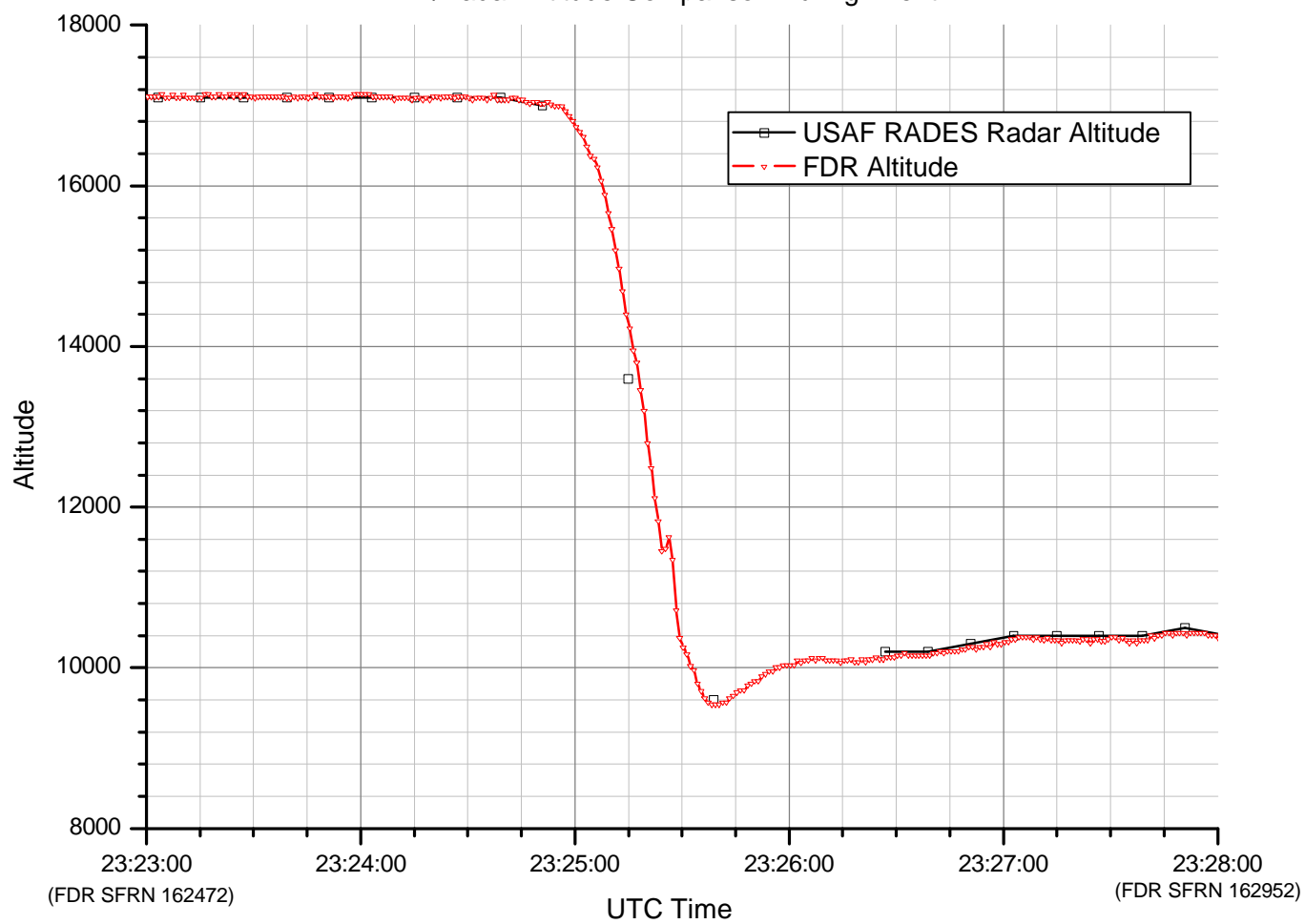
West Palm Beach, FL

- 8000 ft altitude loss, structural damage to horizontal tail and elevator
- Pilots reported using de-icing boots (3 minute activation cycle) and seeing some remnants of ice on boots after boot activation
- Indications from FDR, CVR Ice Detector was active
- Possible SLD conditions (SAT – 4 Deg C)

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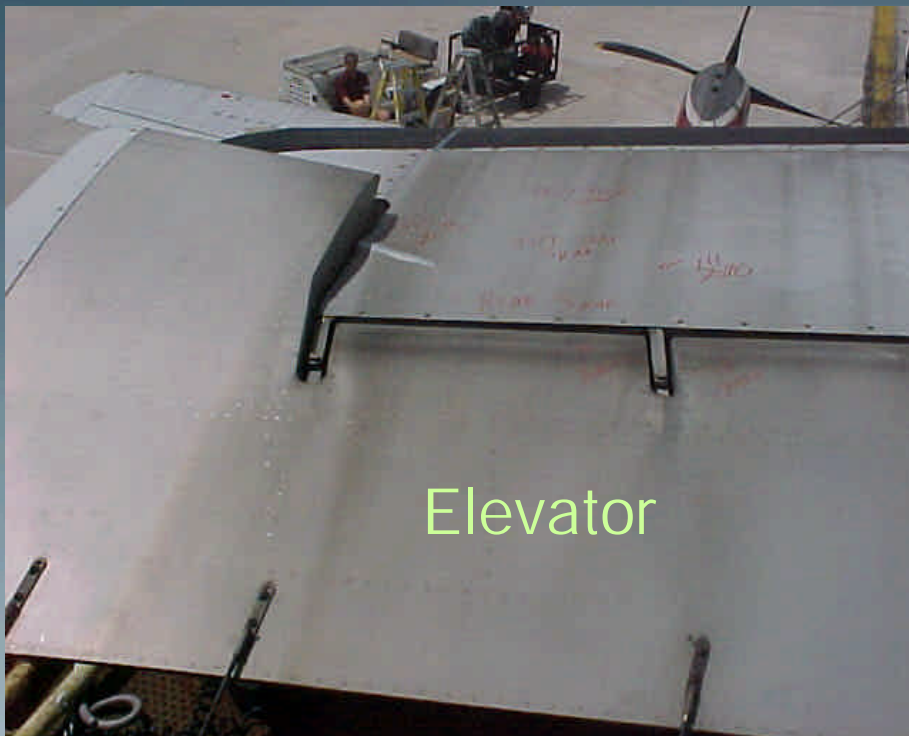
Comair 5054 - March 19, 2001
FDR/Radar Altitude Comparison During Event



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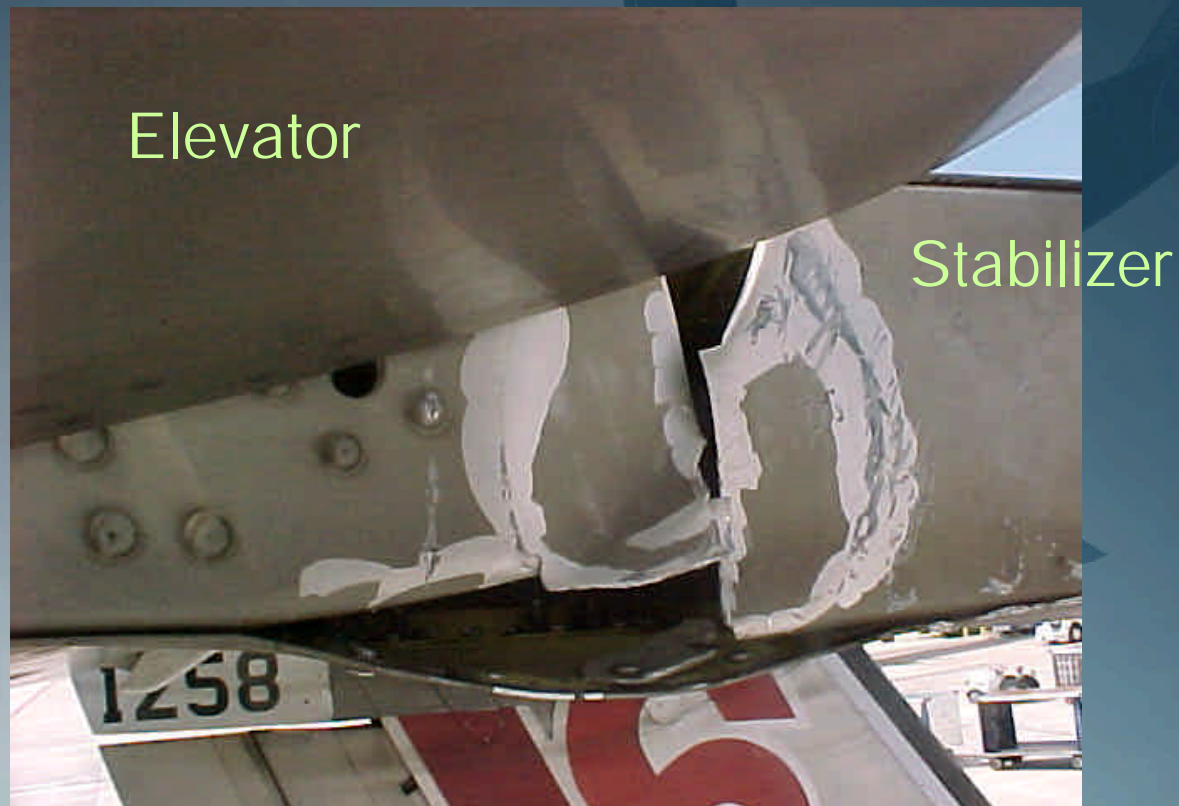
View from above Horizontal Stabilizer



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Right Side Stabilizer, Inboard of Elevator

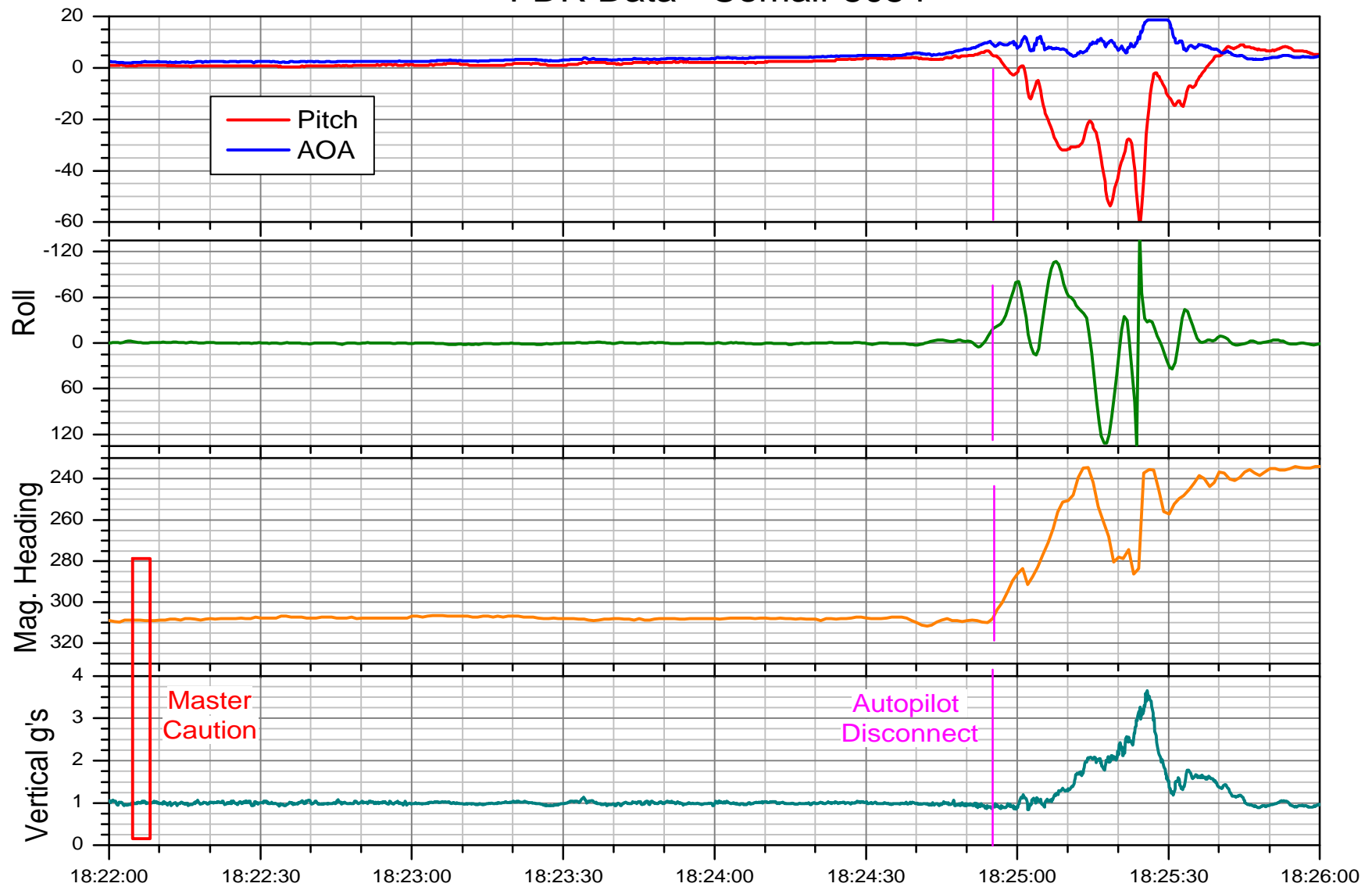


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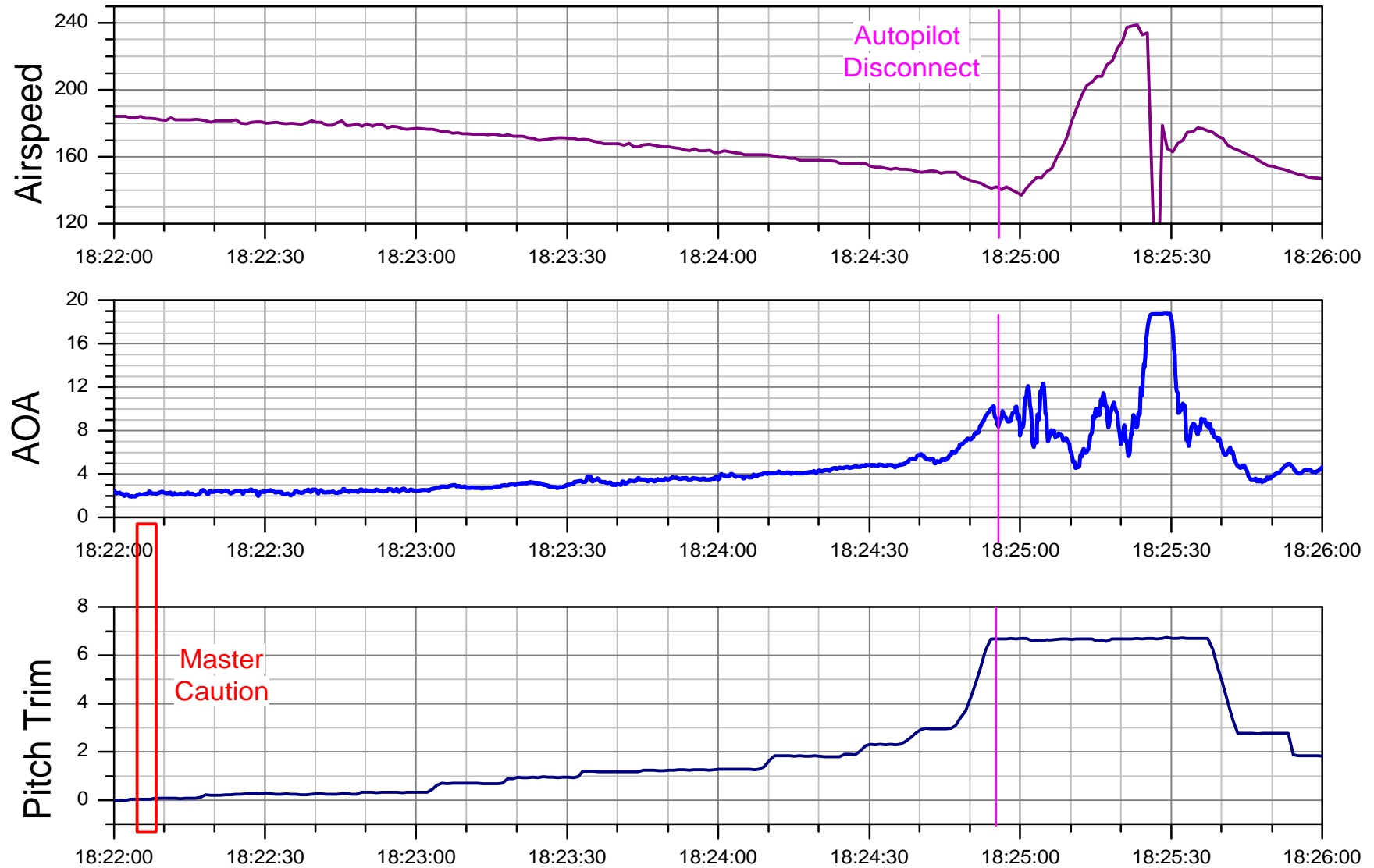
FDR Data - Comair 5054

NTSB



FDR Data - Comair 5054

NTSB



Aerodynamic Coefficient Determination

- NTSB – Direct force calculation from FDR load factor data
 - extracted contributions from engine thrust
 - extract aero coefficients
- Embraer – Utilized their six degree of freedom simulation
 - input FDR recorded control inputs;
 - adjusted aero coefficients to get the simulation to match FDR airplane response
- Only examined “steady” portion prior to autopilot disconnect, prior to and including icing encounter

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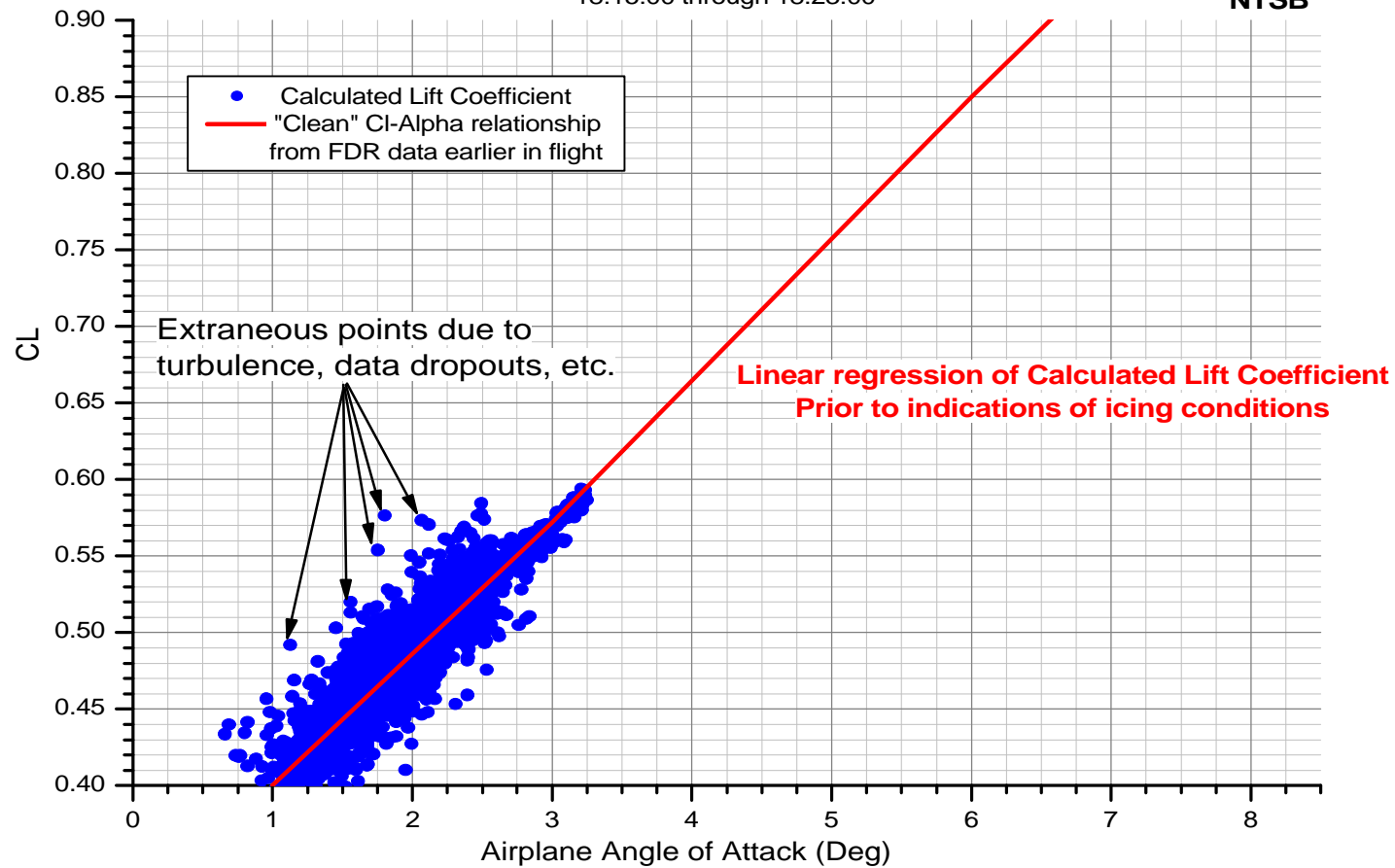
Aerodynamic Coefficient Determination

- During steady portion of FDR data prior to evidence of ice accretion, plotted derived lift coefficient versus recorded angle of attack to derive “clean” airplane lift curve slope (CL_{α})
- Compare “clean” lift curve to the lift coefficient calculated during icing encounter, prior to upset



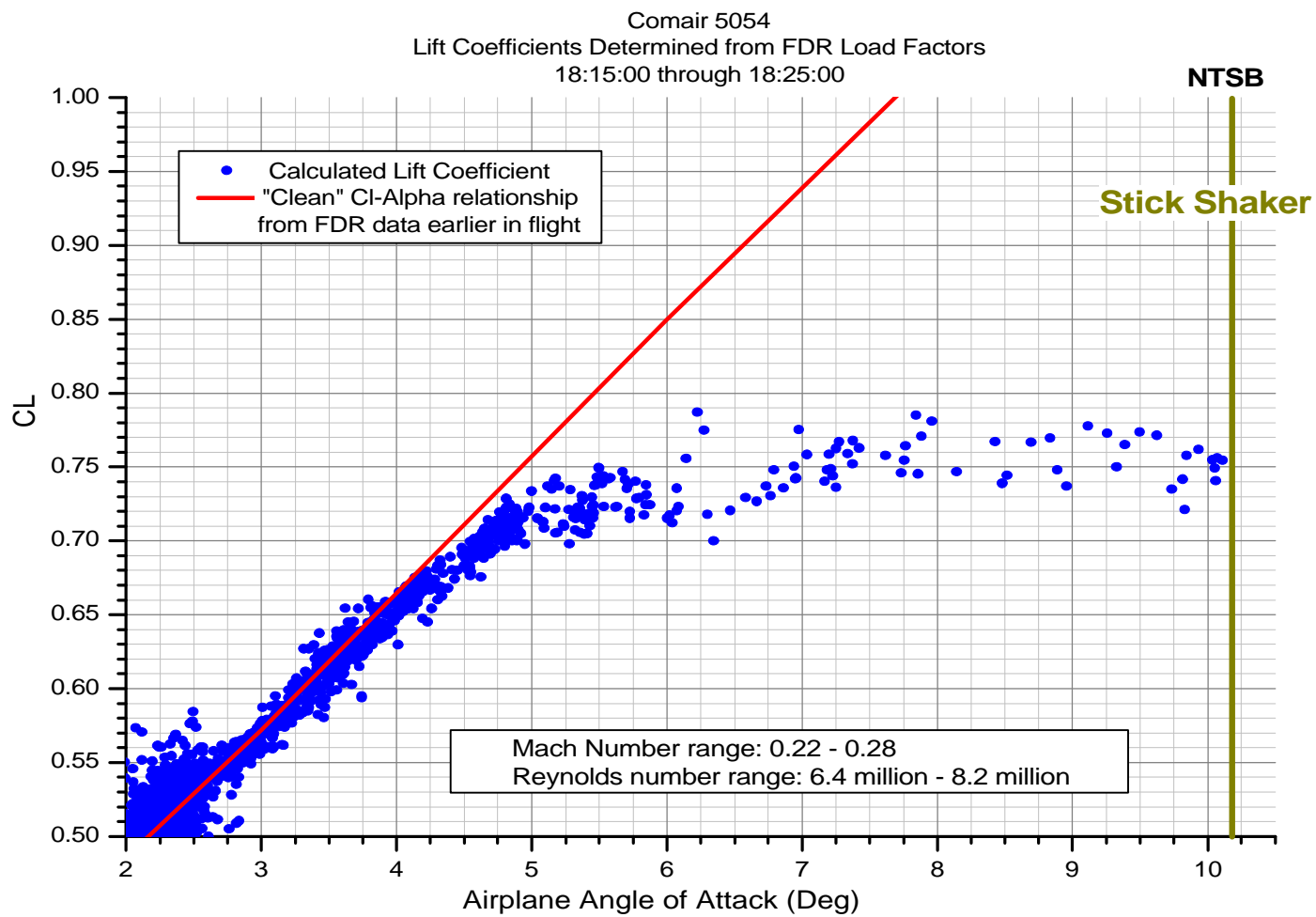
Comair 5054
Lift Coefficients Determined from FDR Load Factors
18:15:00 through 18:23:00

NTSB



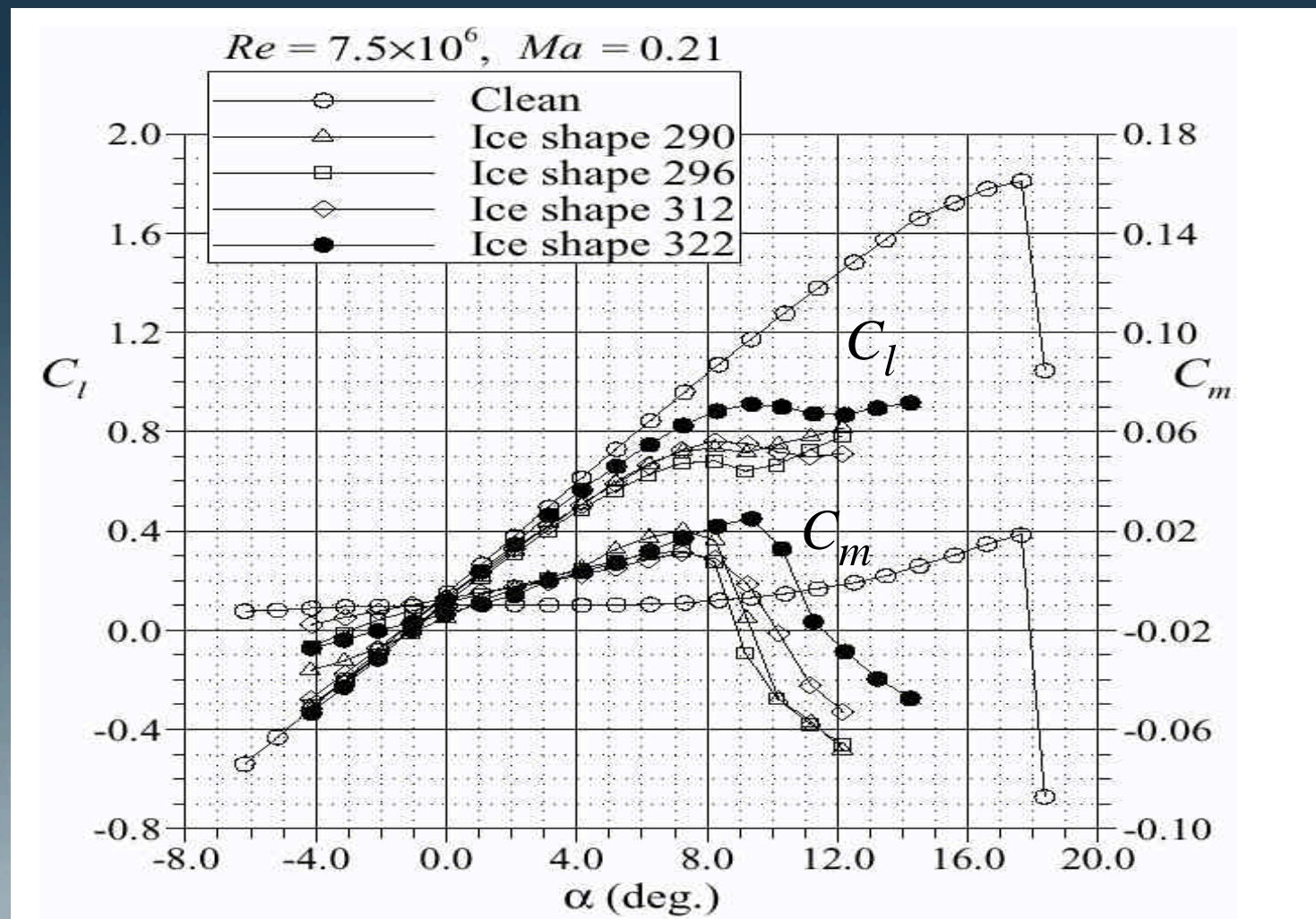
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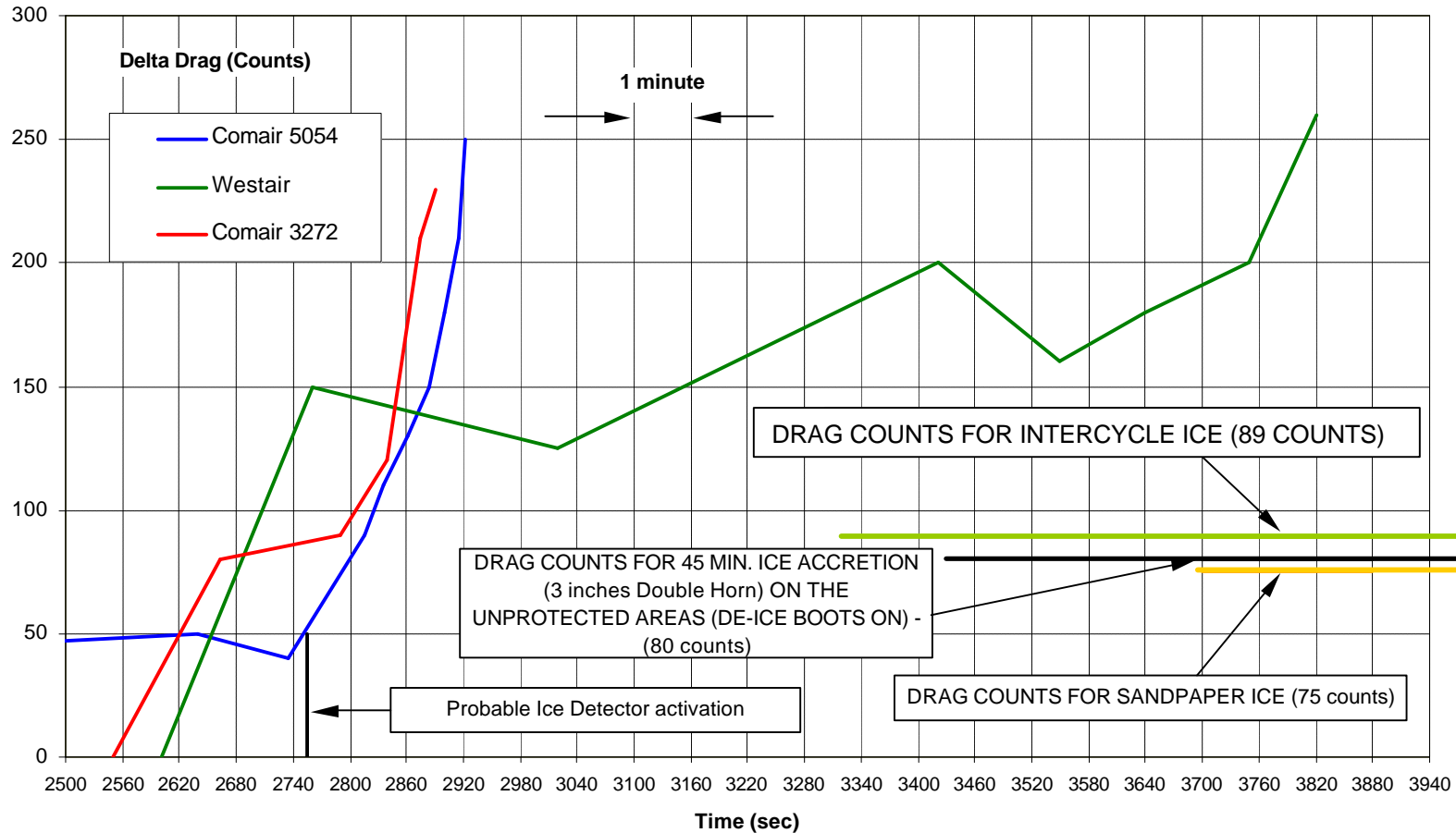
From Broeren, A.P., Addy, H.E., Bragg, M.B., "Effect of Intercycle Ice Accretions on Airfoil Performance"
AIAA-2002-0240

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Embraer Determination of Drag

EMB-120 DRAG DUE TO ICE ANALYSIS
Comparison between Comair 5054, Comair 3272 and Westair



Comair 5054

NTSB Probable cause:

- “The failure of the flight crew to maintain airspeed during an encounter with severe icing conditions, which resulted in an inadvertent stall, loss of control, and structural damage to the airplane. “

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This Accident and other Incidents Demonstrate:

- There still can be a perception amongst some flightcrews that de-ice boots are a “fire and forget” system
- Airplanes are operating in SLD environments for which they are not certified
- Intercycle ice shapes can cause large aerodynamic penalties, larger than some ice shapes currently used in certification

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Embraer Actions for the EMB-120 after this incident

- Issued SB120-25-0258
 - activate de-ice boots and disconnect autopilot at the first sign of ice accretion or at ICE CONDITION illumination.
- Issued SB120-30-0032
 - remove “light-heavy” inflation switch for de-ice boots; only heavy mode available (1 minute inflation cycle)
- Issued SB120-30-0033
 - installation of low speed alarm (160 knots),
- **All were later required by FAA via AD 2001-20-17**

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NTSB Icing Recommendations to the FAA

(Currently Open, not a complete list)

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Recommendations from 1994 Roselawn ATR-72 Turboprop Accident

- **Recommendation A-96-54**
- Revise the icing criteria published in 14 *Code of Federal Regulations*
- Expand the Appendix C icing certification envelope to include freezing drizzle/freezing rain and mixed water/ice crystal conditions
- **Recommendation A-96-56 to FAA**
- Revise the icing certification testing regulations to ensure that airplanes are properly tested for all conditions in which they are authorized to operate
- Provide flightcrews with the means to positively determine when they are in icing conditions that exceed the limits for aircraft certification

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Recommendations from 1997 Monroe, MI, Comair 3272, EMB-120 Turboprop Accident

- **Recommendation A-98-92 To FAA**
- Conduct additional research to identify realistic ice accumulations:
 - intercycle and residual ice accumulations
 - ice accumulations on unprotected surfaces aft of the deicing boots
 - determine the effects and criticality of such ice accumulations
- Information incorporated into aircraft certification requirements and pilot training programs
- **Recommendation A-98-100 to FAA**
- Review the icing certification of all turbopropeller-driven airplanes currently certificated for operation in icing conditions
- Take action to ensure that these airplanes meet the revised icing certification standards.

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Lessons

- Many of the recent incidents and accidents have led to safety improvements
- Upgrades and improvements have come after serious icing events
- Safety Board feels that all the icing related programs, equipment, and procedures should be upgraded and applied to *all* airplanes as a standard process.

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1994 Roselawn, IN, ATR-72 Turboprop, 68 fatal

- **A-96-54 to FAA Status: Open—Acceptable Response**
- Revise the icing criteria published in 14 *Code of Federal Regulations* [CFR], Parts 23 and 25, in light of both recent research into aircraft ice accretion under varying conditions of liquid water content, drop size distribution, and temperature, and recent developments in both the design and use of aircraft. Also, expand the Appendix C icing certification envelope to include freezing drizzle/freezing rain and mixed water/ice crystal conditions, as necessary.
- **A-96-56 to FAA Status: Open—Acceptable Response**
- Revise the icing certification testing regulations to ensure that airplanes are properly tested for all conditions in which they are authorized to operate, or are otherwise shown to be capable of safe flight into such conditions. If safe operations cannot be demonstrated by the manufacturer, operational limitations should be imposed to prohibit flight in such conditions and flightcrews should be provided with the means to positively determine when they are in icing conditions that exceed the limits for aircraft certification

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1997 Monroe, MI, Comair 3272, EMB-120 Turboprop, 39 fatal

- **A-98-92. To FAA Status: Open—Acceptable Response**
- With the National Aeronautics and Space Administration and other interested aviation organizations, conduct additional research to identify realistic ice accumulations, to include intercycle and residual ice accumulations and ice accumulations on unprotected surfaces aft of the deicing boots, and to determine the effects and criticality of such ice accumulations; further, the information developed through such research should be incorporated into aircraft certification requirements and pilot training programs at all levels.
- **A-98-100 to FAA Status: Open—Acceptable Response**
- When the revised icing certification standards and criteria are complete, review the icing certification of all turbopropeller-driven airplanes that are currently certificated for operation in icing conditions and perform additional testing and take action as required to ensure that these airplanes fulfill the requirements of the revised icing certification standards.

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